- Range wind.
- Air temperature.
- Air density.
- Rotation of the earth.

(2) Deflection effects. Some of the deviations from the standard conditions affecting deflection are:

- Drift.
- Crosswind.
- Rotation of the earth.

3-4. Dispersion and Probability

If a number of rounds of ammunition of the same caliber, lot, and charge are fired from the same position with identical settings used for deflection and quadrant elevation, the rounds will not all impact on a single point but will fall in a scattered pattern. In discussions of artillery fire, this phenomenon is called dispersion, and the array of bursts on the ground is called the dispersion pattern.

3-5. Causes of Dispersion

a. The points of impact of the projectiles will be scattered both in deflection and in range. Dispersion is caused by inherent (systemic) errors. It should never be confused with round-to-round variations caused by either human or constant errors. Human errors can be minimized through training and supervision. Corrections to compensate for the effects of constant errors can be determined from the TFT. Inherent errors are beyond control or are impractical to measure. Examples of inherent errors are as follows:

(1) Conditions in the bore. The muzzle velocity achieved by a given projectile is affected by the following:

- Minor variations in the weight of the projectile, form of the rotating band, and moisture content and temperature of the propellant grains.
- Differences in the rate of ignition of the propellant.
- Variations in the arrangement of the propellant grains.
- Differences in the rate of ignition of the propellant.
- Variations in the ramming of the projectile.
- Variations in the temperature of the bore from round to round.

For example, variations in the bourrelet and rotating band may cause inaccurate centering of the projectile, which can result in a loss in achieved range because of instability in flight.

(2) Conditions in the carriage. Deflection and elevation are affected by the following:

- Play (looseness) in the mechanisms of the carriage.
- Physical limitations of precision in setting values of deflection and quadrant elevation on the respective scales.
- Nonuniform reactions to firing stress.

(3) Conditions during flight. The flight of the projectile may be affected by the difference in air resistance created by variations in the weight, achieved muzzle velocity, and projectile. Also, the projectile may be affected by minor variations in wind, air density or air pressure, and air temperature from round to round.

b. The distribution of bursts (dispersion pattern) in a given sample of rounds is roughly elliptical (Figure 3-9) in relation to the line of fire.

c. A rectangle constructed around the dispersion area (excluding any erratic rounds) is called the dispersion rectangle, or 100 percent rectangle. (See Figure 3-10.)

3-6. Mean Point of Impact

For any large number of rounds fired, the average (or mean) location of impact can be determined by drawing a diagram of the pattern of bursts as they appear on the ground. A line drawn perpendicular to the line of fire can be used to divide the sample rounds into two equal groups. Therefore, half of the rounds will be over this line when considered in relation to the weapon. The other half of the rounds will be short of this line in relation to the weapon. This dividing line represents the mean range of the sample and is called the mean range line. A second line can be drawn parallel to the line of fire, again dividing the sample into two equal groups. Half of the rounds will be to the right of this line, and half will be to the left. This line represents the mean deflection of the sample and is called the mean deflection line. (See Figure 3-9.) The intersection of the two lines is the mean point of impact (MPI). (See Figure 3-10.)

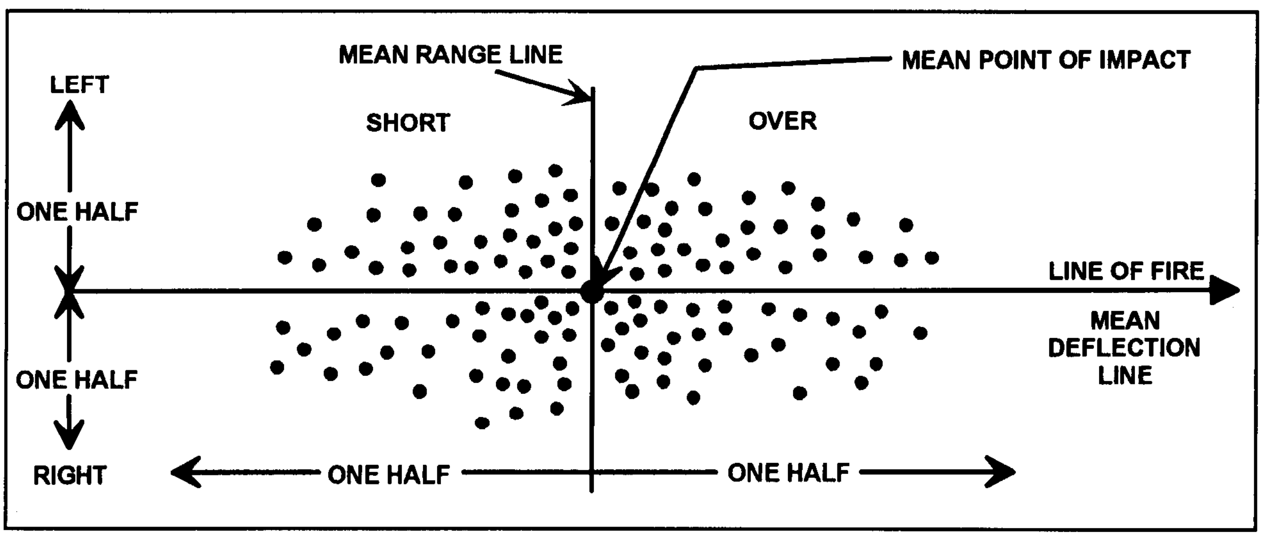

Figure 3-9. Dispersion Pattern.

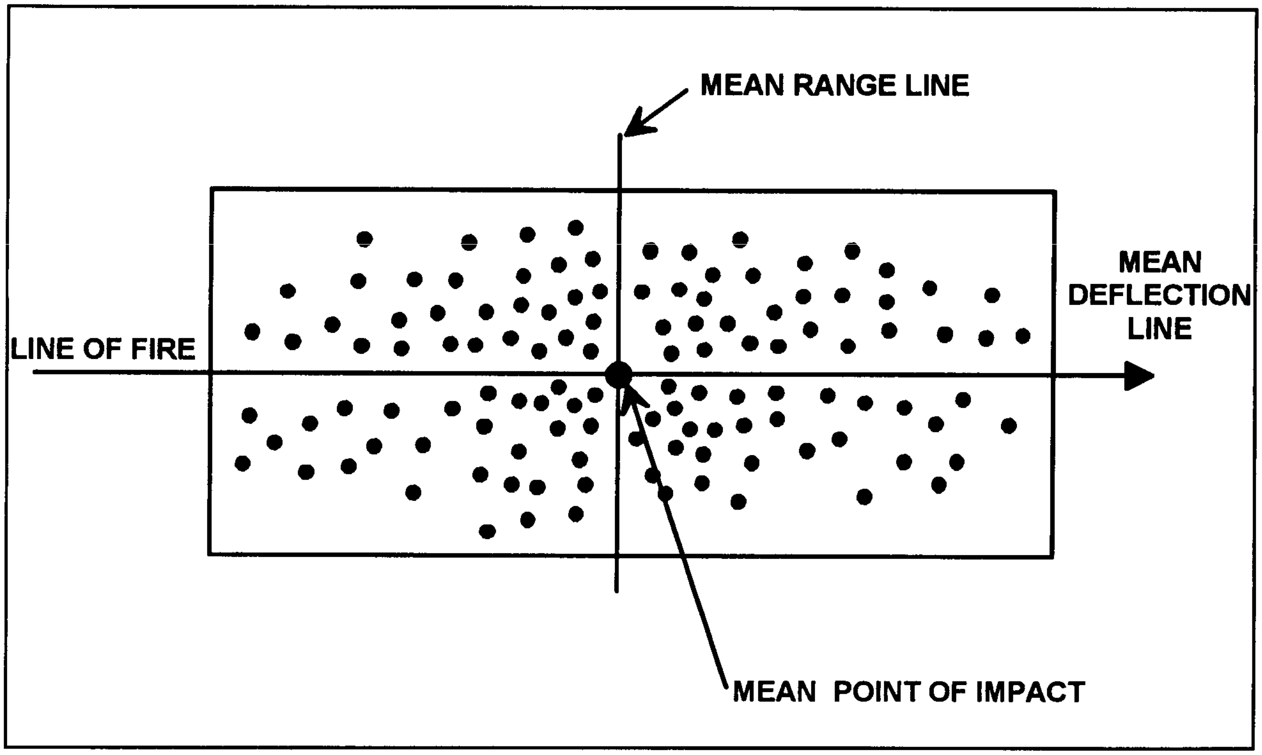

Figure 3-10. Dispersion (100 Percent) Rectangle.

3-7. Probable Error

Probable error is nothing more than an error that is exceeded as often as it is not exceeded. For example, in Figure 3-11, consider only those rounds that have impacted over the mean range line (line AB). These rounds all manifest errors in range, since they all impacted over the mean range line. Some of the rounds are more in error than others. At a point beyond the MPI, a second line can be drawn perpendicular to the line of fire to divide the "ovens" into two equal groups (line CD, Figure 3-11). When the distance from the MPI to line CD is used as a measure of probable error, it is obvious that half of the overs show greater magnitude of error than the other half. This distance is one probable error in range. The range probability curve expresses the following:

a. In a large number of samples, errors in excess and errors in deficiency are equally frequent (probable) as shown by the symmetry of the curve.

b. The errors are not uniformly distributed. Small errors occur more frequently than large errors as shown by the greater number of occurrences near the mean point of impact.

3-8. Dispersion Zones

If the dispersion rectangle is divided evenly into eight zones in range with the value for 1 probable error in range (PER) used as the unit of measure, the percentage of rounds impacting within each zone is as indicated in Figure 3-12. The percentage of rounds impacting within each zone has been determined through experimentation. By definition of probable error, 50 percent of all rounds will impact within 1 probable error in range or deflection of the mean point of impact (25 percent over and 25 percent short or 25 percent left and 25 percent right).

3-9. Range Probable Error

The values for range probable error at various ranges are given in Table G of the tabular firing tables (TFT). These values may be used as an index of the precision of the piece at a particular charge and range. The values for range probable error are listed in meters. Firing Table (FT) values have been determined on the basis of actual firing of ammunition under controlled conditions. For example, FT 155-AM-2 shows that the value of range probable error for charge 5 green bag (GB) at a range of 6,000 meters is 15 meters. On the basis of the 100 percent rectangle, 50 percent of the rounds will impact within 15 meters (over and short) of the mean range line, 82 percent will impact within 30 meters (over and short), 96 percent will impact within 45-meters (over and short), and 100 percent will impact within 60 meters.

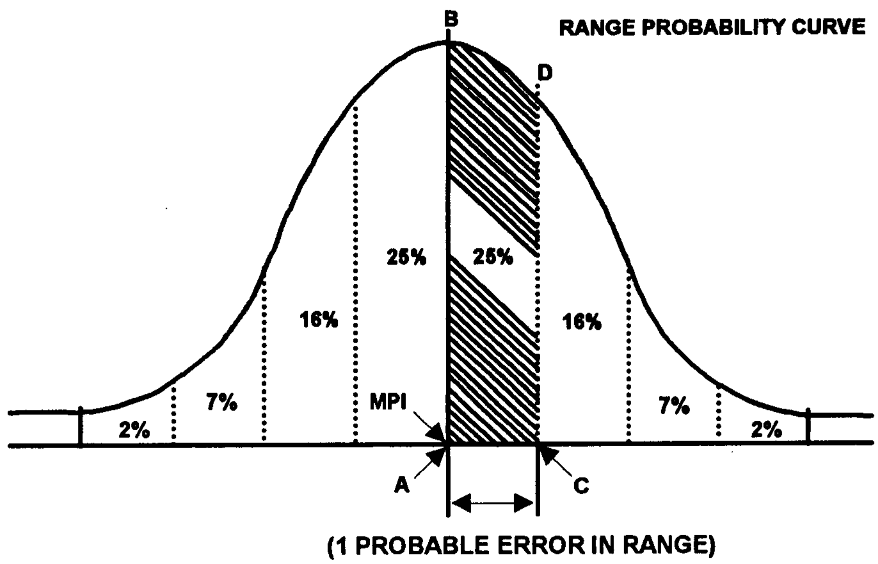

Figure 3-11. Probable Error.

	.02	.07	.16	.25	.25	.16	.07	.02
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004
.07	.0014	.0049	.0112	.0175	.0175	.0112	.0049	.0014
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.25	.0050	.0175	.0400	.0625	.0625	.0400	.0175	.0050
.16	.0032	.0112	.0256	.0400	.0400	.0256	.0112	.0032
.07	.0014	.0049	.0112	.0175	.0175	.0112	.0049	.0014
.02	.0004	.0014	.0032	.0050	.0050	.0032	.0014	.0004

LINE OF FIRE

Figure 3-12. Dispersion Zones.

3-10. Fork

The term *fork* is used to express the change in elevation (in mils) needed to move the mean point of impact 4 probable errors in range. The values of fork are listed in Table F of the firing tables. For example, FT 155-AM-2 shows that the value of fork for a howitzer firing charge 5GB at a range of 6,000 meters is 4 mils. On the basis of the value for probable error in range (paragraph 3-9), adding 4 mils to the quadrant elevation would cause the MPI to move 60 meters. Fork is used in the computation of safety data (executive officer's minimum QE).

3-11. Deflection Probable Error

The values for probable error in deflection (PED) are listed in Table G of the firing tables. For artillery cannons, the deflection probable error is considerably smaller than the range probable error. Values for PED are listed in meters. With the same parameters as those used in paragraph 3-9, the deflection probable error is 4 meters. Therefore, 50 percent of the rounds will impact within 4 meters of the mean deflection line (left and right); 82 percent, within 8 meters (left and right); 96 percent, within 12 meters (left and right); and 100 percent, within 16 meters.

3-12. Time-To-Burst Probable Error

The values of time-to-burst probable error (PETB) (Figure 3-13) are listed in Table G of the firing tables. Each of these values is the weighted average of the precision of a time fuze timing mechanism in relation to the actual time of flight of the projectile. For example, if a 155-mm howitzer fires charge 5GB at a range of 6,000 meters, the value for probable error in time to burst is 0.11 second. As in any other dispersion pattern, 50 percent of the rounds will function within 0.11 second; 82 percent, within 0.22 second; 96 percent, within 0.33 second; and 100 percent within 0.44 second of the mean fuze setting.

3-13. Height-Of-Burst Probable Error

With the projectile fuzed to burst in the air, the height-of-burst probable error (PEHB) (Figure 3-13) is the vertical component of 1 time-to-burst probable error. The height-of-burst probable error reflects the combined effects of dispersion caused by variations in the functioning of the time fuze and dispersion caused by the conditions described in paragraph 3-5(a). The values listed (in meters) follow the same pattern of distribution as for those discussed for range dispersion. These values are listed in Table G of the firing tables.

3-14. Range-To-Burst Probable Error

Range-to-burst probable error (PERB) (Figure 3-13) is the horizontal component of 1 time-to-burst probable error. When this value is added to or subtracted from the expected range to burst, it will produce an interval along the line of fire that should contain 50 percent of the rounds fired. These values are listed in Table G of the firing tables.

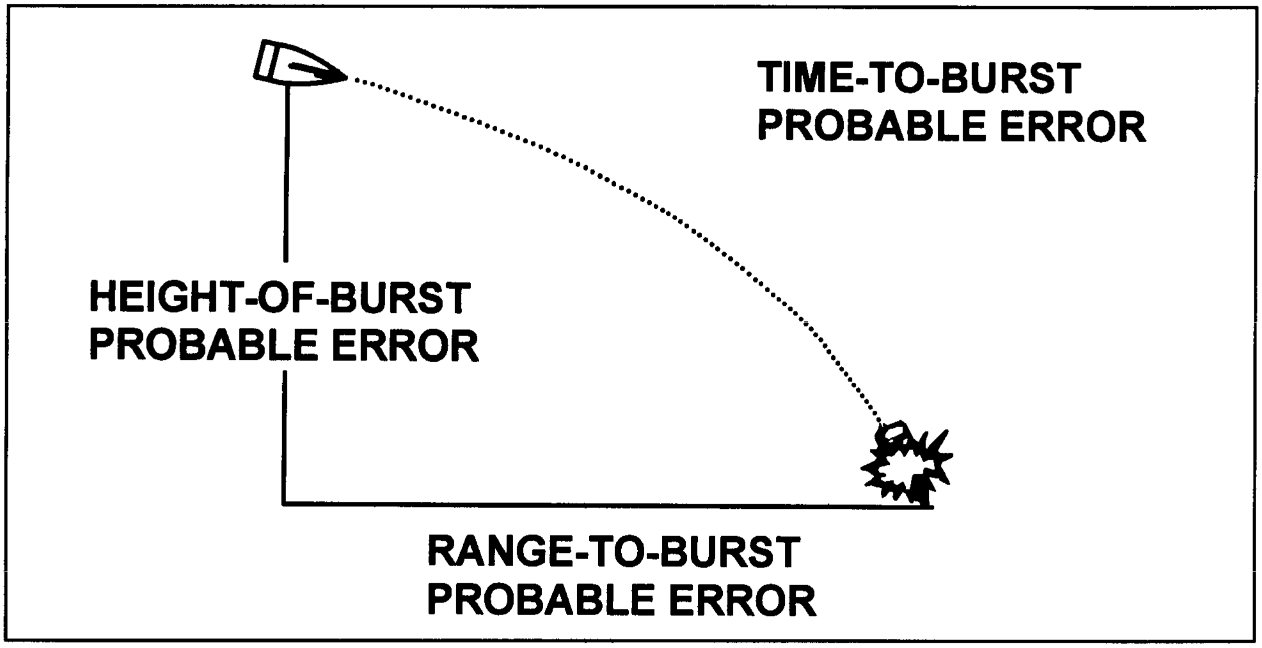

Figure 3-13. Comparison of PE_{HB}, PE_{RB}, and PE_{TB}.